ONE–LOOP RADIATIVE CORRECTIONS TO CHARGINO PAIR PRODUCTION

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We report on the effect that one–loop radiative corrections to the chargino pair production cross section has on the determination of the fundamental parameters of the theory. We work in the context of electron–positron colliders with $\sqrt{s} = 500$ GeV. We conclude that the inclusion of these corrections is crucial in precision measurements, specially at large and small values of $\tan\beta$.

In the Minimal Supersymmetric Standard Model (MSSM) the supersymmetric fermionic partners of the W gauge bosons and the charged Higgs $H^{\pm}$ mix to form a set of two Dirac fermions called charginos $\tilde{\chi}_i^{\pm}$, $i = 1, 2$. The chargino mass matrix is well known:

$$\mathcal{M}_{\mathbf{C}} = \begin{bmatrix} M & \sqrt{2}m_W \cos\beta \\ \sqrt{2}m_W \sin\beta & \mu \end{bmatrix} \tag{1}$$

where M is the gaugino mass associated to the $SU(2)$ group, μ is the supersymmetric higgsino mass, and $\tan\beta = v_2/v_1$ is the ratio of the two Higgs vacuum expectation values (vev). This mass matrix is diagonalized by two rotation matrices $\mathbf{U}$ and $\mathbf{V}$ such that

$$\mathbf{U}^* \mathcal{M}_{\mathbf{C}} \mathbf{V}^{-1} = \text{diag}(m_{\tilde{\chi}_1^{\pm}}, m_{\tilde{\chi}_2^{\pm}}), \tag{2}$$

and every chargino interaction depends on the matrix elements U_{ij} and V_{ij}.

Electron–Positron colliders are a specially clean environment for chargino searches. They are produced in the s–channel via Z and γ gauge bosons, and in the t–channel via electron–sneutrinos:
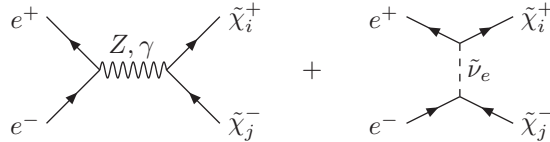
The measurement of the total production cross section, the chargino mass, and the neutralino mass (a decay product), give enough information that can be used to find the fundamental parameters of the theory [1]. This analysis also has been extended to CP violating scenarios and to polarized beams [2], and to the neutralino sector [3].

In order to have reliable results for the fundamental parameters of the theory extracted from chargino observables it is necessary to include the one–loop radiative

corrections to masses and cross section [4,5]. Ref. [4] calculated these quantum corrections including the leading Feynman graphs which contain quarks and squarks, since they are enhanced by large Yukawa couplings. These kind of graphs correct vertices and two point functions in such a way that the corrected amplitudes can be represented by
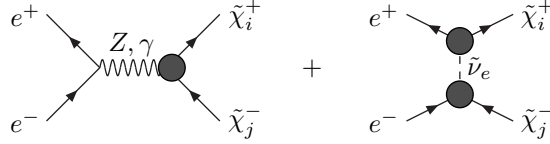
with the renormalized vertices parametrized by form factors as defined in [4]. Each sneutrino vertex has only one form factor:

$$= iC^{-1}(1+\gamma_5)F_{\tilde{\nu}_e}^-,$$

where C is the charge conjugation matrix. The form factor $F_{\tilde{\nu}_e}^-$ receive contributions from chargino mixing and chargino wave function renormalization. In order to be non–vanishing the charginos have to be a mixing between higgsino and gaugino. In this case, corrections proportional to logarithms of squark masses are enhanced by large Yukawa couplings.

The Z gauge boson vertex has the following form factors:

$$= i\,\mathcal{G}_{Z\chi\chi}^{ij}$$

with

$$\mathcal{G}_{Z\chi\chi}^{ij} = (1+\gamma_5)\left[F_{Z0}^+\gamma^\mu + F_{Z1}^+k_1^\mu + F_{Z2}^+k_2^\mu\right] + (1-\gamma_5)\left[F_{Z0}^-\gamma^\mu + F_{Z1}^-k_1^\mu + F_{Z2}^-k_2^\mu\right] \quad (3)$$

and k_1^μ (k_2^μ) is the 4–momenta of the chargino $\tilde{\chi}_j^-$ ($\tilde{\chi}_i^+$). Analogous expressions are valid for the photon form factors. In $\mathcal{G}_{Z\chi\chi}$ we include triangular 1PI graphs, chargino mixing and self energies, and gauge bosons mixing and self energies. The corrections turn out to be enhanced by large Yukawa couplings h_t and h_b, and proportional to logarithms of the squark masses. The corrections for this center of mass energy of 500 GeV can have either sign and go up to values of $\pm 20\%$, $\pm 15\%$, or $\pm 5\%$ for squark mass parameter given by 1 TeV, 600 GeV, or 200 GeV [4].

In the following four figures we plot the tree–level (dashes) and one–loop corrected (solid) total production cross section $\sigma(e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^-)$ as a function of the neutralino mass (LSP). We keep constant the squark mass parameters $M_Q = M_U = M_D = 1$ TeV as well as the trilinear couplings $A_U = A_D = 1$ TeV, and we work with a center of mass energy $\sqrt{s} = 500$ GeV.

In Fig. 1 we consider a constant, one–loop corrected, chargino mass $m_{\tilde{\chi}_1^+} = 170$ GeV, a sneutrino mass given by $m_{\tilde{\nu}_e} = 150$ GeV, and gaugino masses $M = 2M' = 300$ GeV. The parameter $\tan\beta$ is varied along the curve with extreme values

$0.5 < \tan\beta < 100$ and, considering that the chargino mass is constant, this fixes the value of $|\mu|$. Two branches appear according to the sign of μ. In parenthesis, and indicated by arrows it is shown the extreme values of $\tan\beta$ and μ. It is obvious from the figure that the largest deviations occur for extreme values of $\tan\beta$.
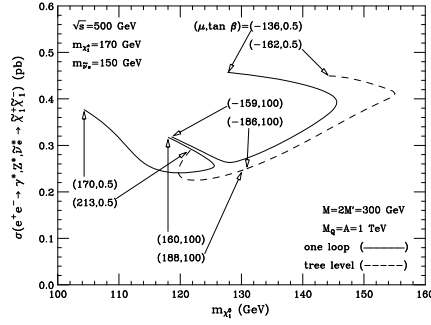

Figure 1: Tree–level and one–loop corrected production cross section of a pair of charginos as a function of the LSP mass. We take $m_{\tilde{\chi}_1^+} = 170$ GeV, $m_{\tilde{\nu}_e} = 150$ GeV, and $M = 2M' = 300$ GeV.

Figure 2: Tree–level and one–loop corrected production cross section of a pair of charginos as a function of the LSP mass. We take $m_{\tilde{\chi}_1^+} = 170$ GeV, $m_{\tilde{\nu}_e} = 150$ GeV, and $M = 2M' = 200$ GeV.
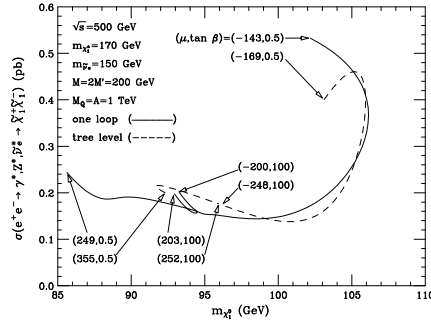
In Fig. 2 we change the gaugino masses to $M = 2M' = 200$ keeping the previous chargino mass $m_{\tilde{\chi}_1^+} = 170$ GeV and sneutrino mass $m_{\tilde{\nu}_e} = 150$ GeV. The main effect is to lower the possible values of the neutralino mass, which is bounded from above approximately by $m_{\tilde{\chi}_1^0} \lesssim \frac{1}{2}M = M'$ (the LSP is mainly gaugino). Notice the proximity of the tree level point $(\mu, \tan\beta) = (355, 0.5)$ and the one–loop corrected $(203, 100)$ which can give and idea of the confusion it may cause the non inclusion of radiative corrections.

In Fig. 3 we have increased the chargino mass with respect to the first figure. Now we have $m_{\tilde{\chi}_1^+} = 200$ GeV, $m_{\tilde{\nu}_e} = 150$ GeV, and $M = 2M' = 300$ GeV. The values of μ are close to the chargino mass, indicating that it is mainly higgsino. The total cross section is smaller, and corrections to the tree level value can be as high as 50%.

Finally, in Fig. 4 we have change the sneutrino mass to $m_{\tilde{\nu}_e} = 600$ GeV compared with the first figure. We maintain the value of the chargino mass $m_{\tilde{\chi}_1^+} = 170$ GeV and the gaugino masses $M = 2M' = 300$ GeV. The effect of increasing the sneutrino mass is to increase the total cross section where there was a large interfer-
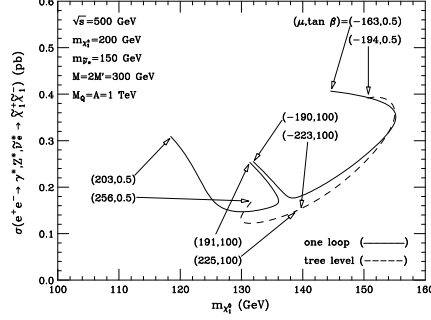
Figure 3: Tree–level and one–loop corrected production cross section of a pair of charginos as a function of the LSP mass. We take $m_{\tilde{\chi}_1^+} = 200$ GeV, $m_{\tilde{\nu}_e} = 150$ GeV, and $M = 2M' = 300$ GeV.
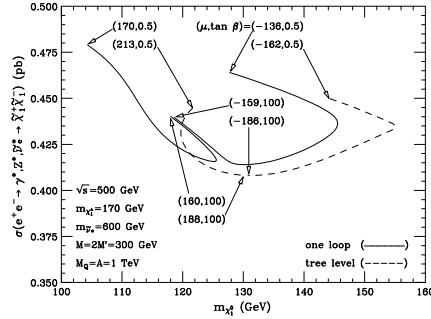

Figure 4: Tree–level and one–loop corrected production cross section of a pair of charginos as a function of the LSP mass. We take $m_{\tilde{\chi}_1^+} = 170$ GeV, $m_{\tilde{\nu}_e} = 600$ GeV, and $M = 2M' = 300$ GeV.

ence effect. In this case there is also a potential confusion in the region of parameter space where the tree level curve at low values of $\tan\beta$ and positive μ intersect the one–loop corrected curves at very large values of $\tan\beta$.

As an example, we consider the second case study in ref. [6], motivated by $SO(10)$ models with non–universal boundary conditions at the GUT scale due to extra D–terms contributions. In this case we have $M = 116.4$ GeV, $\mu = -320.8$ GeV, $m_{\tilde{\nu}_e} = 1018.2$ GeV, and $\tan\beta = 47$, typical of $SO(10)$ models with top–bottom–tau Yukawa unification. Squark masses are of the order of 800 GeV. We observe a 4.3% correction to the total cross section $\sigma_{11} = \sigma(e^+e^- \to \tilde{\chi}_1^+ \tilde{\chi}_1^-)$, and comparable corrections for the chargino masses. The corrections on $\sigma_{12} = \sigma(e^+e^- \to$

Table 1: Tree–level and one–loop chargino observables from the second case study in ref. [6].

observable	tree–level	one–loop	correction
$m_{\tilde{\chi}_1^+}$ (GeV)	109.9	112.6	+2.5%
$m_{\tilde{\chi}_2^+}$ (GeV)	342.3	359.0	+4.8%
σ_{11} (pb)	0.73	0.76	+4.3%
σ_{12} (fb)	8.4	7.0	−16%

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$\tilde{\chi}_1^+ \tilde{\chi}_2^-) + \sigma(e^+e^- \to \tilde{\chi}_2^+ \tilde{\chi}_1^-)$ is larger and negative (-16%). As a point of comparison we mention that it is expected to measure experimentally the chargino mass at the 0.1% level. We conclude that the inclusion of one–loop radiative corrections to the chargino observables is necessary in order to obtain reliable results in the determination of the fundamental parameters from experimental measurements.

Acknowledgments

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